ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Laboratory for Safety Analysis INSTITUTE FOR ENERGY TECHNOLOGY

DMAVT Departement Maschinenbau & Verfahrenstechnik: Department of Mechanical & Process Engineering

Grundlagen der technischen Risikoanalytik

Transport gefährlicher Güter

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Transport gefährlicher Güter

- Usually, production and consumption of dangerous goods are spatially separated (e.g. car fuel)
- Dangerous goods have to be transported, more than 10’000 substances known
- Economic growth results in an increase of dangerous goods to be transported
- Transportation means: rail, cars, pipelines, ships, planes (of minor importance)

Differences Between Stationary and Mobile Systems

Feature	Stationary system	Mobile system
System	Numerous components	Simple (related to the transportation mean), complex (related to the whole transportation system)
System environment	Constant, invariant	Changing
System influences	Few, constant	Numerous, changing
Process parameter	Numerous	Few (related to the transportation means)
Type of energy	Physical (potential), chemical	Physical (potential, kinetic), chemical energy
Decanting processes	Depending on the installation	Very frequent (related to the whole system)

Bahnunfall „Affoltern“ (1/3)

Bahnunfall Affoltern (2/3)

Unfallhergang

- Am 08. März 1994 (08:10 Uhr) entgleisen fünf von zwanzig Zisternenwagen mit je 80'000 Litern Benzin nahe des Bahnhofs Affoltern.
- Vier Wagen kippen, entgleisen und geraten in Brand.
- Lokomotive und sieben Kesselwagen fahren aufgrund der abgerissenen Kupplung unbehelligt weiter.
- Acht nicht entgleiste Wagen werden rechtzeitig aus der Gefahrenzone entfernt.

Benzinausbreitung

- Über die Kanalisation gelangt Benzin
- ein 800 m entferntes Regenklärbecken, das kurz darauf explodiert
- die ca. 7 km entfernte Kläranlage Glatt und in die Glatt selbst

Schäden

- eine schwerverletzte Passantin (weggeschleuderter Schachtdeckel)
- Sachschäden in Millionenhöhe

Ursache

- technisches Versagen (Radlagerdefekt)

Bahnunfall "Affoltern“ (3/3)

Bahnstrang mit Transport gefährlicher Gütern
Zug und Transport auf der Basis best. Sicherheitsanforderungen (Regeln)
Annahme: "Heissläufer" gibt es nicht oder sind in der Folge unbedeutend
⇒ keine spezifischen Detektoren und Sensoren

Unfallgeschehen ohne Risikomanagement	**Unfallgeschehen mit Risikomanagement**
• für die Situation unzureichende technische Ausstattung (Sensoren usw.) • keine Notfallplanung **aber** • eine verletzte Person, keine Toten • Sachschäden	vorausschauende Planungen mit einfachstem Modell (van den Brand) **erwartet**: 240 Tote • **potentielle Folgen** - schnellstmögliche Evakuierung - Panik (Tote, Verletzte, ...) • **Modellmangel**: zu konservativ, Kanalisation bleibt unberücksichtigt

Purposes of a Risk Analysis

- Base for decision making
  - Comparison of different transportation routes
  - Comparison of different transportation means for a specific route
  - Optimisation of transportation systems (amount per trip, timetable, improved containment)
  - Minimisation of hazards for the environment (e.g. related to the pollution of ground water), restrictions
- Fulfilling authoritative requirements
  - Criteria for the construction of new roads and rail tracks
- Stakeholder interaction
  - Comparison of transportation risk as base of acceptance discussions

Preparation of a Risk Analysis TdG

- Description of transportation system
- Date of dangerous good to be transported
- Environmental, geographical, population and weather data
- Regulations
- Empirical values
- Selection of analytical methods

Transportation of dangerous goods

International transportation regulation

- Reglement concernant le transport international ferroviaire de marchandises dangereuses (RID)
- Accord européen relatif au transport international des marchandises dangereuses par route (ADR)

Risk regulation in Switzerland

- Major accidents ordinance (StFV) [1]
- Ordinance on the transport of dangerous goods by rail (RSD)
- Ordinance on the transport of dangerous goods by road (SDR)

Guidelines of the StFV

Description of the surroundings

- Population density
- Ground water
- Surface water
- Special objects (e.g. shopping centre, camping ground, dangerous industrial facilities, etc.) …

Estimation of undesired event frequency

Accident scenarios

- Fire
- Explosion
- Toxic gas release
- Release of water endangering substances
- Release of mineral oil products

Rail – Release frequency calculation

$$H_S = DAG_{RS} \cdot UR \cdot W \cdot RFZ \cdot ASS$$

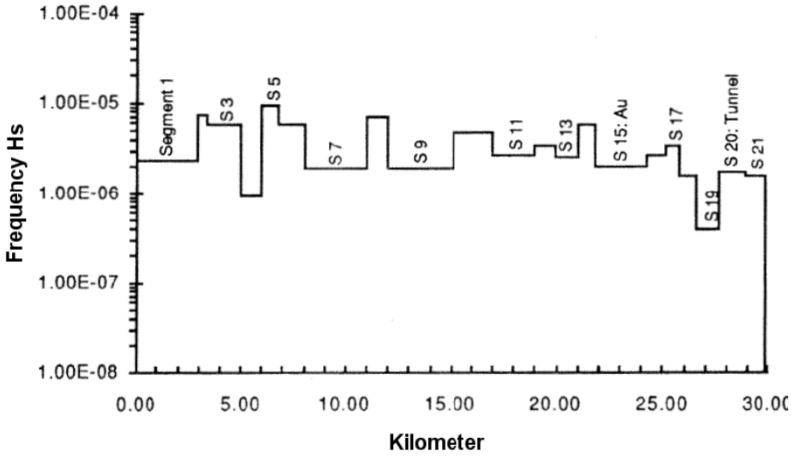
H_S:	Frequency of a representative release scenario which causes heavy damage [km^{-1} a^{-1}]
DAG_{RS}:	Mean annually number of freight trains, which transport relevant substances [trains/a]
UR:	Accident rate [train^{-1} km^{-1}]
W:	Probability, that a wagon loaded with dangerous goods will be damaged or derailed in case of an accident [-]
RFZ:	Rate for relevant releases and (in case of fire and explosion) a following ignition [-]
ASS:	Number of representative accident scenarios which cause heavy damage [-]

Road – Release frequency calculation

$$H_S = DTV \cdot 365 \cdot ASV \cdot UR \cdot AGS \cdot ASK \cdot ARS \cdot RFZ \cdot ASS$$

H_S:	Frequency of a representative release scenario which causes heavy damage [km^{-1} a^{-1}]
DTV:	Daily mean traffic is calculated to yearly traffic [vehicles/a]
ASV:	Share of heavy vehicle traffic on the DTV [-]
UR:	Accident rate [vehicle^{-1} km^{-1}]
AGS:	Share of dangerous goods transports on the heavy vehicle traffic [-]
ASK:	Share of the decisive SDR-classes on the representative accident scenario [-]
ARS:	Share of the relevant substances on the decisive SDR-classes for the representative accident scenario [-]
RFZ:	Rate for relevant releases and (in case of fire and explosion) a following ignition [-]
ASS:	Number of representative accident scenarios which cause heavy damage [-]

More advanced methods e.g.: Frequency of harm to the population



More advanced methods

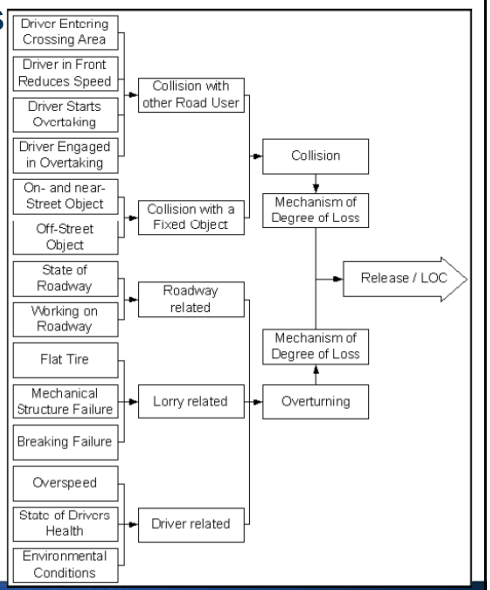
Basic concept

Loss of containment frequency

- Frequencies of transportations
- Basic event probabilities
- Human behaviour
- Segment parameters / characteristics

Consequence calculations

- Substance characteristics
- Amount transported
- Accident/impact scenarios (pool, fire, BLEVE, explosion, Intoxination)

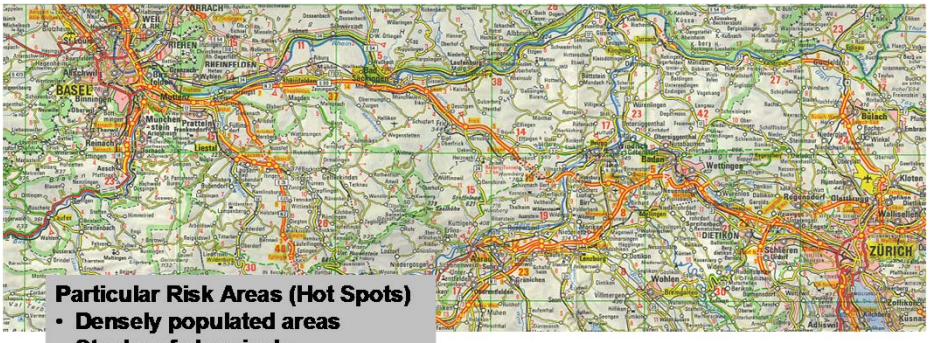


More advanced methods: Hot Spots

The concept of Hot Spots:

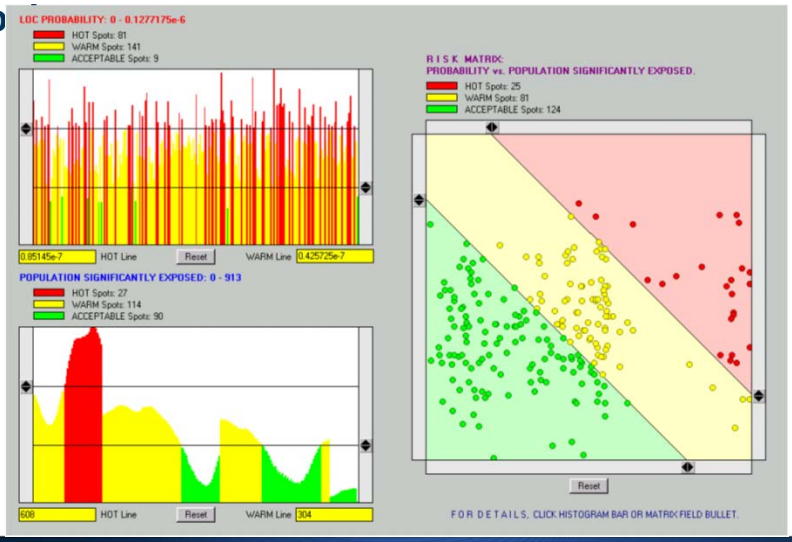
"A hot spot is defined by the existence of at least one infrastructural sensitive object in the vicinity of the actual
location, and/or by the fact that the location has a high population density irrespective of the existence of an object." [3]

Spatial Distribution of the Risk (1/2)

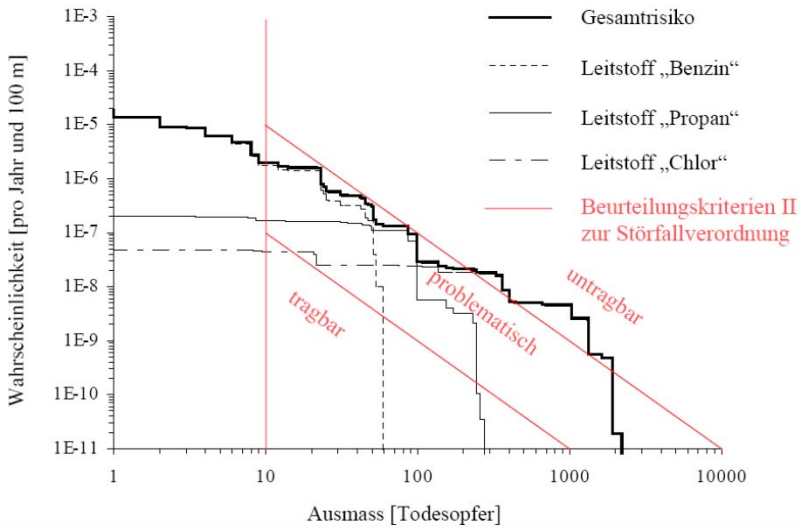


Particular Risk Areas (Hot Spots)
- **Densely populated areas**
- **Stocks of chemicals**
- **Stocks of fuel**
- **Environmental sensitive areas**
- **Ground water reservoir**
- **Tunnels**
- **Intersections**
- **High traffic volume**

Spatial Distribution of the Risk (2/2) – CARGO to



Risk Representation per 100 Meter



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